

**GCE**

**Chemistry A**

**H032/01: Breadth in chemistry**

Advanced Subsidiary GCE

**Mark Scheme for November 2020**

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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## Annotations

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
	Benefit of doubt given
	Contradiction
	Rounding error
	Error in number of significant figures
	Error carried forward
	Level 1
	Level 2
	Level 3
	Benefit of doubt not given
	Noted but no credit given
	Ignore

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

<b>Annotation</b>	<b>Meaning</b>
<b>DO NOT ALLOW</b>	Answers which are not worthy of credit
<b>IGNORE</b>	Statements which are irrelevant
<b>ALLOW</b>	Answers that can be accepted
( )	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
<b>ECF</b>	Error carried forward
<b>AW</b>	Alternative wording
<b>ORA</b>	Or reverse argument

## SECTION A

Question	Answer	Marks	AO element	Guidance
1	C	1	1.2	
2	C	1	1.2	
3	B	1	1.1	
4	A	1	1.1	
5	A	1	2.1	
6	A	1	1.2	
7	B	1	1.2	
8	C	1	1.2	ALLOW 4
9	A	1	2.2	
10	B	1	2.6	
11	C	1	2.6	
12	D	1	1.1	
13	B	1	1.2	ALLOW 0.054(0)
14	A	1	1.2	
15	C	1	1.1	
16	C	1	1.1	
17	A	1	1.2	
18	C	1	2.8	ALLOW 36.7
19	B	1	1.2	
20	C	1	2.6	
	<b>Total</b>	<b>20</b>		

## SECTION B

Question		Answer					Marks	AO element	Guidance	
21	(a)	Shell	1st shell	2nd shell	3rd shell	4th shell	1	1.1		
		Electrons	2	8	18	32				
		Requires all 4 numbers to be correct ✓								
	(b)	<b>Differences:</b> (Different number of) neutrons ✓  <b>Similarities:</b> (Same number of) protons <b>AND</b> electrons ✓					2	1.1×2	<b>IGNORE</b> different masses/mass numbers throughout ( <i>Question asks for atomic structures</i> )  <b>ALLOW</b> 'amount' for 'number' <b>ALLOW</b> 'electron configuration' for electrons	
	(c)	(i)	<b>FIRST CHECK ANSWER ON THE ANSWER LINE</b> <b>If answer = 35.48 (to 2 DP) award 2 marks</b>  $\frac{(35 \times 75.76) + (37 \times 24.24)}{100} \text{ OR } 35.4848 \text{ OR } 35.485 \checkmark$  = 35.48 (to 2 DP) ✓					2	1.2×2	<b>For 1 mark: ALLOW ECF</b> → to 2 DP if: <ul style="list-style-type: none"> <li>• %s used with wrong isotopes <b>ONCE</b></li> <li><b>OR</b></li> <li>• transposed decimal places for <b>ONE %</b></li> <li><b>AND</b></li> <li>• calculated <math>A_r</math> is between 35 and 37</li> </ul>
	(c)	(ii)	$m/z = 72: {}^{35}\text{Cl}{}^{37}\text{Cl}$ <b>OR</b> Contains chlorine-35 <b>AND</b> chlorine-37 ✓  $m/z$ values: 70 <b>AND</b> 74 ✓					2	3.1  3.2	

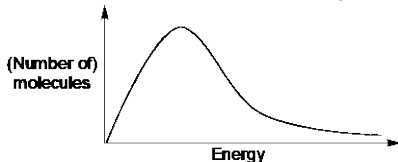
Question			Answer	Marks	AO element	Guidance
22	(a)	(i)	(1s <sup>2</sup> )2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>5</sup> ✓  Look carefully at 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> – there may be a mistake	1	1.2	<b>ALLOW</b> 3d after 4s <sup>2</sup> , e.g. 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 4s <sup>2</sup> 3d <sup>10</sup> 4p <sup>5</sup> <b>ALLOW</b> upper case D, etc and subscripts, e.g. ....4S <sub>2</sub> 3D <sub>1</sub>  <b>DO NOT ALLOW</b> [Ar] as shorthand for 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup>  <b>IGNORE</b> 1s <sup>2</sup> repeated
	(a)	(ii)	P <sub>4</sub> + 6Br <sub>2</sub> → 4PBr <sub>3</sub> ✓	1	2.6	<b>ALLOW</b> multiples
	(b)		Giant ionic ✓  In solid state/lattice, ions are fixed (in position) <b>OR</b> cannot move <b>AND</b> In liquid state, ions are mobile <b>OR</b> can move ✓	2	1.1          1.2	<b>'Giant'</b> is essential  Mark independently of 1st structure mark  <b>IGNORE</b> comments about electrons for solid  <b>IGNORE</b> 'free' ions

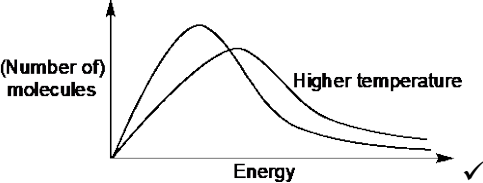
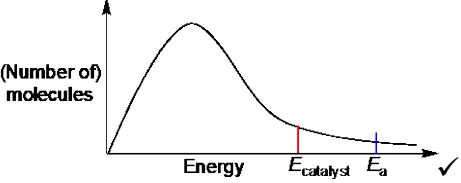
Question	Answer	Marks	AO element	Guidance
(c)	<p><b>FIRST CHECK ANSWER LINES</b>  <b>If molecular formula = BrF<sub>5</sub> AND 174.6/175 AND working showing use of ideal gas equation</b>  <b>Award 5 marks for calculation</b></p> <hr style="border-top: 1px dashed #00aaff;"/> <p><b>Rearranging ideal gas equation</b>  <math display="block">n = \frac{pV}{RT} \checkmark</math> <b>Unit conversion AND substitution into <math>n = \frac{pV}{RT}</math>:</b> <ul style="list-style-type: none"> <li>• <math>R = 8.314</math> <b>OR</b> 8.31</li> <li>• <math>V = 76(.0) \times 10^{-6}</math> (m<sup>3</sup>)</li> <li>• <math>T</math> in K: 373 K</li> </ul> e.g. <math>\frac{1.00 \times 10^5 \times 76.0 \times 10^{-6}}{8.314 \times 373} \checkmark</math>  <b>Calculation of <math>n</math> using <math>p, V, R</math> AND <math>T</math></b>  <math>n = 2.45 \times 10^{-3}</math> (mol) <math>\checkmark</math></p> <p><b>Calculation of <math>M</math></b>  <math display="block">M = \frac{0.428}{2.45 \times 10^{-3}} = 174.6 \checkmark</math></p> <p><b>Molecular formula</b>                  BrF<sub>5</sub> <b>OR</b> F<sub>5</sub>Br <math>\checkmark</math></p>	5	2.2×4	<p><b>ALLOW ECF throughout</b></p> <p><b>IF <math>n = \frac{pV}{RT}</math> is omitted, ALLOW</b> when values are substituted into rearranged ideal gas equation.</p> <p><b>ALLOW</b> conversion of <math>V</math> into dm<sup>3</sup> <b>AND</b> <math>p</math> in kPa                  Gives same answer in powers of 10</p> <p>Calculator value:                  from 8.314 = 2.450725899 × 10<sup>-3</sup>                  from 8.31 = 2.45190555 × 10<sup>-3</sup>  <b>IGNORE</b> figures after 5 in 2.45</p> <p><b>ALLOW ECF</b> from a value of <math>n</math> that has been derived from <math>pV = nRT</math></p> <p>e.g. 0.174.6 <b>OR</b> 0.175 from 2.45</p> <p><b>ALLOW ECF</b> matching <b>ECF <math>M</math></b> from <math>pV = nRT</math></p>
	<p><b>Use of 24 dm<sup>3</sup></b></p> <p>Final 2 marks possible for use of 76.0 cm<sup>3</sup> <b>OR</b> 0.760 dm<sup>3</sup> by <b>ECF</b></p> <p>e.g. <math>n = \frac{76.0}{24000} = 3.17 \times 10^{-3}</math> <b>No mark (calculation much simpler)</b></p> <p><math>M = \frac{0.428}{3.17 \times 10^{-3}} = 135 \checkmark</math> <b>ECF</b></p> <p>BrF<sub>3</sub> <math>\checkmark</math> <b>ECF</b></p>			

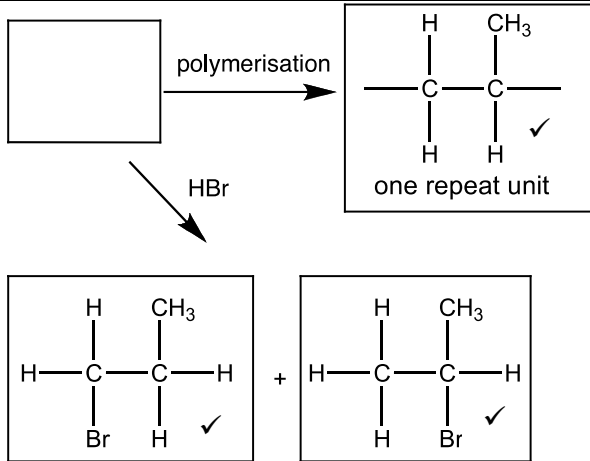
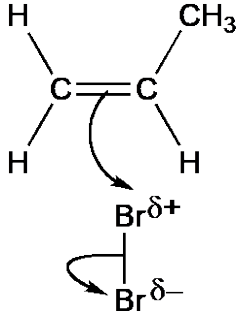
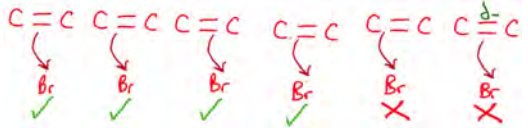


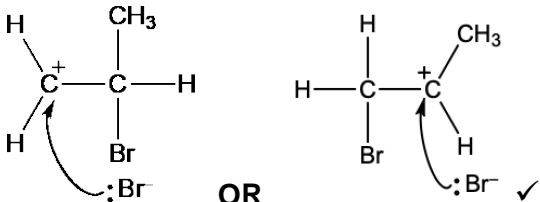
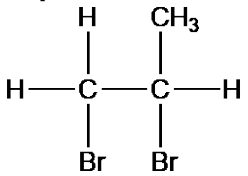
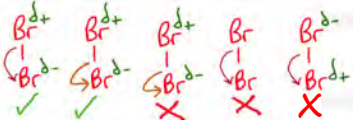
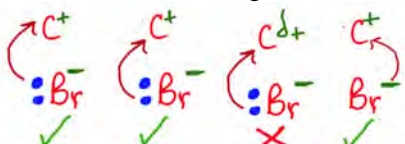
Question		Answer	Marks	AO element	Guidance	
23	(a)	<p><b>FIRST CHECK ANSWER ON THE ANSWER LINE</b> If answer = 0.454 (mol dm<sup>-3</sup>) award 3 marks If answer = 0.227 (mol dm<sup>-3</sup>) award first 2 marks</p> <hr style="border-top: 1px dashed blue;"/> <p><math>n(\text{Ba(OH)}_2)</math> in 100 cm<sup>3</sup> <span style="float:right"><b>1 mark</b></span> <math>= \frac{3.89}{171.3} = 0.0227\dots (\text{mol}) \checkmark</math> <b>3 SF or more</b></p> <p><b>Concentration of OH<sup>-</sup></b> <span style="float:right"><b>2 marks</b></span> <math>n(\text{Ba(OH)}_2) \times 2 = 2 \times 0.0227</math> <math>= 0.0454\dots (\text{mol}) \checkmark</math></p> <p>Use of <math>\times 10 = 10 \times 0.0454</math> Concentration of OH<sup>-</sup> = 0.454 (mol dm<sup>-3</sup>) <math>\checkmark</math> <b>3 SF required</b></p>	3	<p>3.1x2</p> <p>3.2</p>	<p>ALLOW ECF throughout</p> <p>ALLOW use of 171 within working (Use of Ar: Ba 137 rather than 137.3)</p> <p>Calculator: 0.02270869819 IGNORE figures after 7 in 0.0227</p> <p>ALLOW working with <math>\times 10</math> before <math>\times 2</math></p> <p>Use of <math>\times 10 = 10 \times 0.0227</math> <math>= 0.227\dots (\text{mol}) \checkmark</math></p> <p>Use of <math>\times 2 = 2 \times 0.227</math> Concentration of OH<sup>-</sup> = 0.454 (mol dm<sup>-3</sup>) <math>\checkmark</math> <b>3 SF required</b></p> <p><u>Common error</u> 0.227 no <math>\times 2</math> <b>2 marks</b></p>	
	(b)	(i)	(Titres that agree) within 0.1 cm <sup>3</sup> $\checkmark$	1	2.3	<p>ALLOW within 0.05 cm<sup>3</sup></p> <p>ALLOW ml for cm<sup>3</sup></p> <p>If cm<sup>3</sup> units are absent, <b>ASSUME</b> cm<sup>3</sup> <b>BUT</b> <b>DO NOT ALLOW</b> incorrect units, e.g. dm<sup>3</sup>; mol dm<sup>-3</sup></p>

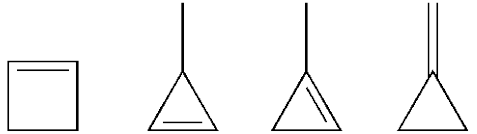
Question		Answer	Marks	AO element	Guidance
(b)	(ii)	<p><b>FIRST CHECK ANSWER ON THE ANSWER LINE</b>  <b>If answer = 0.0856 (mol dm<sup>-3</sup>) award 3 marks</b></p> <hr style="border-top: 1px dashed #00AEEF;"/> $n(\text{HNO}_3) = 0.160 \times \frac{26.75}{1000} = 4.28 \times 10^{-3} \text{ (mol) } \checkmark$ $n(\text{Ba}(\text{OH})_2) \text{ in } 25.0 \text{ cm}^3 = \frac{4.28 \times 10^{-3}}{2} = 2.14 \times 10^{-3} \text{ (mol) } \checkmark$ $\text{Concentration} = 2.14 \times 10^{-3} \times \frac{1000}{25} = 0.0856 \text{ (mol dm}^{-3}\text{) } \checkmark$	3	2.8x2    2.4	<p>Use ECF throughout</p> <p><b>DO NOT ALLOW</b> <math>4.3 \times 10^{-3}</math>  <b>BUT</b> remaining marks available by ECF                      e.g.  <math>4.3 \times 10^{-3} \div 2 = 2.15 \times 10^{-3} \checkmark</math> <b>ECF</b>  <math>2.15 \times 10^{-3} \times \frac{1000}{25} = 0.086 \checkmark</math> <b>ECF</b></p>
(c)		<p><b>Route 1</b>  <i>Reactant:</i>                      Add water (to Ba) <b>OR</b> H<sub>2</sub>O in equation <math>\checkmark</math></p> <p><i>Balanced equation:</i>  <math>\text{Ba} + 2\text{H}_2\text{O} \rightarrow \text{Ba}(\text{OH})_2 + \text{H}_2 \checkmark</math></p> <p><b>Route 2</b>  <i>Balanced equation with O<sub>2</sub></i>  <math>2\text{Ba} + \text{O}_2 \rightarrow 2\text{BaO} \checkmark</math></p> <p><i>Balanced equation with H<sub>2</sub>O</i>  <math>\text{BaO} + \text{H}_2\text{O} \rightarrow \text{Ba}(\text{OH})_2 \checkmark</math></p>	4	3.3  2.6  3.3  3.3	<p><b>ALLOW</b> multiples in equations</p> <p>Balanced equation automatically collects 2 marks for Route 1</p> <p><b>ALLOW</b> 1 mark for <b>BOTH</b> reactants in route 2: i.e. React with O<sub>2</sub> <b>AND</b> then with H<sub>2</sub>O</p> <p><b>NOTE</b>                      3 correct balanced equations <math>\rightarrow</math> 4 marks</p>

Question		Answer	Marks	AO element	Guidance
24	(a)	<p><b>FIRST CHECK THE ANSWER ON ANSWER LINE</b> If answer = <math>-46</math> (<math>\text{kJ mol}^{-1}</math>) award 3 marks</p> <p><b>Use of <math>\Delta_c H</math> values and balancing numbers</b> <math>\pm (+180 + (3 \times -286))</math> OR <math>\pm 678</math> <b>AND</b> <math>\pm (2 \times -293)</math> OR <math>\pm 586</math> seen anywhere ✓</p> <p><b>Correct subtraction using <math>\Delta H</math></b> <math>(-678) - (-586)</math> <math>= -92</math> (<math>\text{kJ mol}^{-1}</math>) ✓</p> <p><b>Calculation of <math>\Delta_f H(\text{NH}_3)</math> formation</b> <math>\Delta_f H(\text{NH}_3) = \frac{-92}{2} = -46</math> (<math>\text{kJ mol}^{-1}</math>) ✓</p>	3	2.6 × 3	<p><b>FULL ANNOTATIONS MUST BE USED</b></p> <p><b>ALLOW ECF</b> throughout</p> <p><b>COMMON ERRORS</b></p> <p><math>-92</math> omission of <math>\div 2</math> for <math>\Delta_f H(\text{NH}_3)</math> <b>2 marks</b>  <math>(+)</math>46 Incorrect subtraction <b>2 marks</b>  <math>(+)</math>92 Incorrect subtraction &amp; no <math>\div 2</math> <b>1 mark</b></p> <p><math>-385</math> no <math>\times 2</math> for <math>-293</math> and no <math>\div 2</math> <b>1 mark</b>  <math>-192.5</math> no <math>\times 2</math> for <math>-293</math> <b>2 marks</b></p> <p><math>(+)</math>480 no <math>\times 3</math> for <math>-286</math> and no <math>\div 2</math> <b>1 mark</b>  <math>(+)</math>240 no <math>\times 3</math> for <math>-286</math> <b>2 marks</b></p> <p><math>(+)</math>187 no <math>\times 3</math> for <math>-286</math> <b>AND</b> no <math>\times 2</math> for <math>-293</math>  <b>AND</b> no <math>\div 2</math> <b>1 mark</b></p> <p><math>(+)</math>93.5 no <math>\times 3</math> for <math>-286</math> <b>AND</b> no <math>\times 2</math> for <math>-293</math> <b>2 marks</b></p>
	(b)	<p><b>Boltzmann distribution (seen anywhere) 2 marks</b></p>  <p><b>Curve</b> Curve starts close to origin (<b>ALLOW</b> flexibility) <b>AND</b> curve does not touch x axis at high energy ✓</p> <p><b>Labels</b> (Number of) molecules/particles <b>AND</b> Energy ✓</p>	5	1.1 × 2	<p><b>FULL ANNOTATIONS THROUGHOUT</b></p> <p><b>NOTE:</b> Look for marking criteria within annotations on Boltzmann distribution diagram</p> <p><b>IGNORE</b> slight inflexion on the curve  <b>IGNORE</b> small increase at end of curve  <b>For labels,</b>  <b>ALLOW</b> kinetic energy  <b>IGNORE</b> number of atoms  <b>IGNORE</b> enthalpy for energy</p>

Question	Answer	Marks	AO element	Guidance
	<p><b>Curves for two temperatures</b> <span style="float: right;"><b>1 mark</b></span></p>  <p><b>Catalyst and activation energy</b> <span style="float: right;"><b>1 mark</b></span></p>  <p><b>Molecules and activation energy, <math>E_a</math></b> <span style="float: right;"><b>1 mark</b></span></p> <p><b>Explanation</b> At higher temperature <b>OR</b> in presence of catalyst</p> <p>More molecules/particles/collisions</p> <ul style="list-style-type: none"> <li>• have energy above activation energy <b>OR have enough energy to overcome <math>E_a</math></b> ✓</li> </ul> <p><i>Could be shown on diagram(s) using shaded area with annotations</i></p>		1.2x3	<p><b>Temperature</b> Drawing of <b>two</b> labelled curves <b>AND</b> higher temperature peak at higher energy <b>AND</b> lower on molecules <b>IGNORE</b> curves meeting at higher energy</p> <p>Higher temperature curve must cross over <b>ASSUME</b> that <math>T_2</math> is higher temperature than <math>T_1</math></p> <p><b>Catalyst</b> <math>E_c</math> shown at lower energy than <math>E_a</math> on Boltzmann distribution</p> <p><b>IGNORE</b> catalyst provides a lower activation energy <i>Boltzmann distribution not used</i></p> <p><b>ALLOW</b> more molecules have energy to react</p> <p><b>ALLOW</b> <math>E_a</math> for activation energy <b>ALLOW</b> <math>E_c</math> for activation energy with catalyst</p> <p><b>IGNORE</b> more successful collisions <b>OR</b> collide more frequently</p>

Question		Answer	Marks	AO element	Guidance
25	(a)	 <p>polymerisation</p> <p>HBr</p> <p>one repeat unit</p>	3	2.5×3	<p><b>ALLOW</b> any combination of skeletal <b>OR</b> structural <b>OR</b> displayed formula as long as unambiguous</p> <p><b>For repeat unit,</b></p> <ul style="list-style-type: none"> <li>• ‘side bonds’ required on either side of repeat unit from C atoms</li> <li>• <b>DO NOT ALLOW</b> &gt; one repeat unit</li> </ul> <p><b>IGNORE</b> brackets</p> <ul style="list-style-type: none"> <li>• <b>IGNORE</b> <math>n</math></li> </ul> <p><b>ALLOW</b> in either order</p>
	(b)	 <p>1st curly arrow Curly arrow from double bond to Br of Br–Br ✓ <b>DO NOT ALLOW</b> partial charge on C=C</p> <p>2nd curly arrow Correct dipole on Br–Br <b>AND</b> curly arrow for breaking of Br–Br bond ✓</p>	4		<p><b>ANNOTATE ANSWER</b> For curly arrows, <b>ALLOW</b> straight or snake-like arrows and small gaps (see examples)</p> <hr style="border-top: 1px dashed #00aaff;"/> <p><b>1st curly arrow</b> must</p> <ul style="list-style-type: none"> <li>• go to a Br atom of Br–Br</li> </ul> <p><b>AND</b></p> <ul style="list-style-type: none"> <li>• start from, <b>OR</b> be traced back to <b>any point across width</b> of C=C</li> </ul>  <p><b>2nd curly arrow</b> must</p> <ul style="list-style-type: none"> <li>• start from, <b>OR</b> be traced back to, <b>any part of</b> <math>\delta^+ \text{Br} - \text{Br} \delta^-</math> bond</li> <li>• <b>AND</b> go to Br <math>\delta^-</math></li> </ul>

Question	Answer	Marks	AO element	Guidance
	<p>3rd curly arrow  <b>Correct carbocation</b> with + charge on C with 3 bonds  <b>AND</b> curly arrow from Br<sup>-</sup> to C<sup>+</sup> of carbocation</p> <p><b>DO NOT ALLOW</b> δ+ on C of carbocation</p>  <p><i>i.e. <b>ALLOW</b> carbonium + on either C atom</i></p> <p><b>Correct product to match mechanism</b> ✓</p>  <p><b>DO NOT ALLOW</b> half headed or double headed arrows but allow <b>ECF</b> if seen more than once</p>			 <p><b>3rd curly arrow</b> must</p> <ul style="list-style-type: none"> <li>• go to the C<sup>+</sup> of carbocation</li> </ul> <p><b>AND</b></p> <ul style="list-style-type: none"> <li>• start from, <b>OR</b> be traced back to <b>any point across width</b> of lone pair on :Br<sup>-</sup></li> <li>• <b>OR</b> start from - charge on Br<sup>-</sup> ion</li> </ul>  <p>(Lone pair <b>NOT</b> needed if curly arrow shown from - charge on Br<sup>-</sup>)</p> <p><b>2.5</b></p> <p><b>2.5</b></p> <p><b>ALLOW</b> bromonium ion</p> <p><b>ALLOW</b> any combination of skeletal <b>OR</b> structural <b>OR</b> displayed formula as long as unambiguous</p> <p><b>NOTE:</b> For a mechanism with HBr,  <b>ALLOW</b> all marks <b>EXCEPT</b> for final product</p>
(c)	(i)	2	1.1×2	<p><b>IGNORE</b> reference to physical properties  <b>IGNORE</b> same general formula  <b>DO NOT ALLOW</b> same empirical <b>OR</b> molecular formula</p> <p>Differs by CH<sub>2</sub> is <b>not</b> sufficient (<i>no successive</i>)  <b>ALLOW</b> differs by CH<sub>2</sub> each time <b>AW</b></p>

Question		Answer	Marks	AO element	Guidance
(c)	(ii)	$C_nH_{2n-2}$ ✓	1	3.2	<b>ALLOW</b> $C_nH_{2(n-1)}$
(c)	(iii)	$H_3C-C\equiv C-H + 2Br_2 \longrightarrow H_3C-\overset{\overset{Br}{ }}{C}-\overset{\overset{Br}{ }}{C}-H$ <p>Left-hand side, i.e. Reactants, balanced with <math>2Br_2</math> ✓            Right-hand side, i.e. Product ✓</p>	2	2.5 2.6	<b>ALLOW</b> any combination of skeletal <b>OR</b> structural <b>OR</b> displayed formula as long as unambiguous  <b>ALLOW</b> $C_3H_4$ for $H_3CC\equiv CH$ <i>Questions asks only for structure of product</i>  <b>ALLOW</b> $H_3CCBr_2CHBr_2$ <b>OR</b> $H_3CCBr_2CBr_2H$
(c)	(iv)	Any 2 structures from: $H_3C-C\equiv C-CH_3$ $H_2C=C(H)-C(H)=CH_2$ $H_2C=C(H)-CH_3$ 	2	3.2x2	<b>ALLOW</b> any combination of skeletal <b>OR</b> structural <b>OR</b> displayed formula as long as unambiguous
(c)	(v)	$H_3C-\overset{\overset{CH_3}{ }}{C}-C\equiv C-\overset{\overset{CH_3}{ }}{C}-CH_2-CH_3$ ✓	1	2.5	<b>ALLOW</b> any combination of skeletal <b>OR</b> structural <b>OR</b> displayed formula as long as unambiguous

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